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DETERMINATION OF THE AMOUNT OF OXYGEN CONTAINED IN A LIQUID AT ATMOSPHERIC PRESSURE

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The air in a fluid adversely affects the operation of hydraulic control systems of installations and mechanisms. Sometimes the presence of air in a hydraulic system is completely inadmissible. When the pressure drops below atmospheric in a hydraulic system, the air is released from the fluid and occupies a certain volume in some part of the system (elbows of the piping, dead-end section, closed spaces etc.). On an increase in pressure the previously released air cannot be rapidly dissolved in the liquid, it begins to be compressed, an air trap is formed, thus making it necessary to apply considerable force to move the controlling elements. After performing the operation and removing the load, decompression can occur in certain sections of the piping which involves the formation of "air cushions." The presence of "air cushions" in the hydraulic system can lead to an improper arrangement of the control unit, which hampers their regulation.

The air can be released from the fluid as bubbles under the effect of variable pressure in the cavities of the power cylinder. The

air bubbles, changing in volume under a load, partly cause a fluctuating delivery of the working fluid.

All other things being equal, pump performance depends also on the air content in the liquid. When investigating cavitation phenomena, when evaluating the degree of compressibility of a fluid, it is important to know the content of air dissolved in the fluid.

The above examples show how important it is to know how much air is contained in liquids used in hydraulic systems and to what extent it is released from the liquids at different evacuations.

We will call a volume of air reduced to normal conditions (pressure 760 mm Hg, temperature $+4^{\circ}$) liberated at a given evacuation from 1 cm^3 of solvent the coefficient of liberation δ. Then

$$\delta = \frac{Q_a}{Q_1} 100\%,$$

where Q_a is the volume of liberated air reduced to standard conditions;

Q_1 is the volume of liquid from which the air was liberated.

The instruments used to determine the air content in the liquid can be divided into two groups: single action and continuous control.

The single action instruments include those developed by K. K. Shal'nev, D. S. Tsikis and R. M. Svetlovk, L. A. Epshteyn and also the device developed by N. M. Tikhonov and N. V. Morozova.

Degasification of a liquid in these instruments is done either by creating several streams of liquid in the degasing vessel (Shal'nev's instrument), or by agitating the sample with a magnetic stirrer (Tsiklis and Svetlova's instrument), or by continuous shaking of the sample for a certain time (Epshteyn's instrument).

The most perfected instruments are those of Shal'nev, Tikhonova, and Morozova. In these instruments there occurs complete degasification of the liquid and the duration of the experiment is not great.

The effect of the pressure of the saturated vapors of the test liquid was excluded by installing a moisture trap.

The use of a large amount of mercury (more than 20 kg) and the complexity of the device and experimental procedure are the main faults of these instruments.

Continuous control instruments are less used in practice. They are based on the use of complex physical laws, for example, on the measurement of the heat conductivity of the extracted gases or on the absorption of ultrasound in the degased sample etc. The main shortcoming of these instruments is the need for their careful calibration and a comparatively long duration for obtaining the results.

In the present work we will describe a method for determining the amount of air contained in a liquid, applicable under any laboratory and aerodrome conditions, without the use of mercury. For the proposed method we used Epshteyn's instrument with certain modifications.

The instrument is simple to make and operate. The results of the experiment, with consideration of the estimate of the error of this instrument, are completely satisfactory.

Device for Determining the Amount of Air Contained in a Liquid

The device consists of three glass vessels 1, 4, and 8 which are connected by tubes to stopcocks 3, 5, and 12. Stopcock 12 is three-way, the others are two-way. Stopcocks 2 and 12 are designed to fill vessel 1 with the test liquid. Vessel 8 is connected through stopcock 9 to the vacuum pump. A vacuum-gage is connected to stopcock 7.

Vessels 4 and 8 are connected by a U-shaped water manometer 11 for measuring the pressure drop in these vessels during the experiment. A small tank with the volume of 8 cm^3 is connected by a rubber tube

to stopcock 12. The tank can be freely raised above the vessels.

The vessels and manometer are attached on a flat shield of the instrument which is suspended on the wall close to the vacuum pump. The attachment of the vessels and manometer makes it possible during the experiment to shake the contents of the vessels by hitting with a rubber hammer or by hand along the shield (to accelerate the process of air liberation).

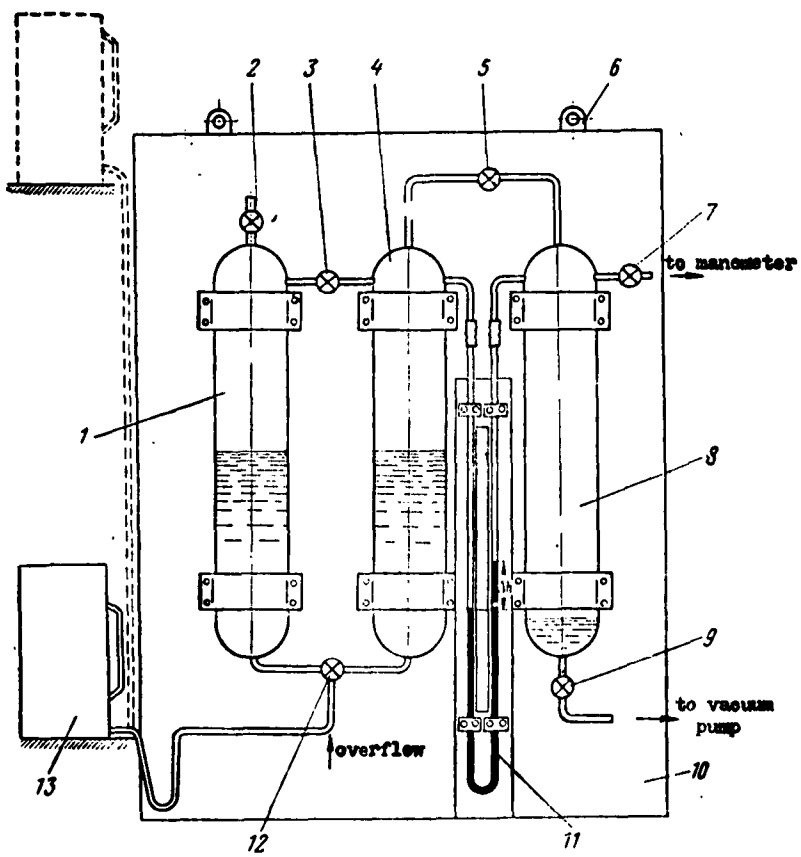

Fig. 1. Diagram of the device for determining the amount of air contained in the liquid. 1, 4, and 8) glass vessels; 2, 3, 5, 7, and 9) two-way vacuum stopcock; 10) shield; 11) manometer; 12) three-way vacuum stopcock; 13) tank; 6) suspension hook.

The method used in the present work can be used for testing the gas saturation of samples taken from hydraulic systems and units.

For this purpose the sampler can be the first vessel, which should be easy to remove from the shield of the device. The removed sampler is connected by one stopcock to the hydraulic system whose fluid is being investigated, the other stopcock connects the volume of the sampler with the ambient medium. When the entire cylinder is flooded, a portion of the liquid overflows and then both stopcocks are closed. In order to exclude the effect of the pressure of saturated vapors on the experimental results, a certain volume of the investigated fluid, preliminarily degased, is allowed to flow into vessel 8.

The stopcocks are greased with vacuum lubricants before the test.

Order of Performing Experiment and its Result

With stopcock 3 closed (stopcock 2 and 12 are open), vessel 1 is filled from the bottom with the test liquid, afterwards stopcocks 2 and 12 are shut off. Vessels 4 and 8 and differential manometer are exhausted through stopcock 9 by means of the vacuum to the necessary evacuation (stopcock 5 is open). Then stopcock 5 is shut off and stopcock 3 and 12 are open. The liquid flows from vessel 1 into vessel 4; degasification occurs during the flow.

The coefficient of liberation is calculated by the formula

$$\delta = \frac{pV_2}{p_0 V_1},$$

where p is the pressure of the liberated air;

p_0 is the atmospheric pressure;

V_1 is the volume of vessel 1;

V_2 is the volume of vessel 4.

If $V_1 = V_2$ and water is the liquid in the manometer, a drop of pressure at the manometer Δh = 100 mm will correspond to each per cent of air liberated from the solution.

The coefficient of liberation δ was determined for the following oils: AMG-10F, A and B. The selection of these liquids was because we wanted to investigate the content of air in oil AMG-10F, the most widely used in aircraft hydraulic systems, and also to evaluate the ability of the new oils A and B to absorb air at atmospheric pressure (Table 1).

TABLE 1

Physical Properties of Tested Oils

Oil	Specific weight γ in g/cm^3 (at 20°)	Viscosity ν in cm^2/sec (at 20°)
AMG-10F	0,834	21,2
A	0,935	49,6
B	0,951	23

The results of investigating these oils are given below.

Oil AMG-10F. During the first 20-25 min of the experiment the liberation of air occurs especially vigorously with considerable foaming. The amount of air liberated is greater, the smaller the residual pressure. Then a pressure drop, recorded by the differential manometer, increases slowly and becomes constant on termination of air liberation.

Figure 2 shows the coefficient of liberation versus the degree of exhaustion.

The points obtained in the experiment (Table 2) have a certain scattering which is explained by the dissimilar experimental conditions: different temperature (room temperature varied from 28 to 23°; the liquid samples were collected from different batches). However, the character of the dependence $\delta = f(p_{vac})$ is fully determined—all experimental points, with small deviations, fit on one straight line proceeding from the origin of the coordinates.

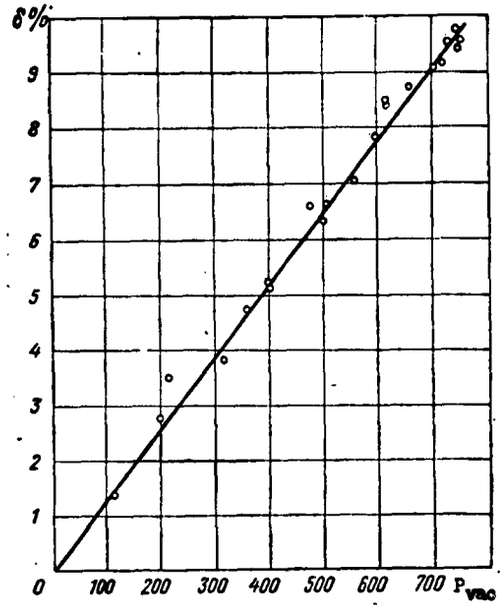

Fig. 2. Coefficient of liberation of oil AMG-10F versus exhaustion p_{vac} ($t = 20\text{-}23^{\circ}$).

The maximum coefficient of liberation $\delta = 9.62\%$ was obtained at $p_{res} = 13$ mm Hg. By extrapolating the obtained relation, we will derive the value of coefficient δ in a complete vacuum. This value we will designate by δ_{max} and call it the coefficient of solubility. For oil AMG-10F $\delta_{max} = 9.72\%$. The experimental relation $\delta = f(p_{vac})$ is nicely described by the following formula:

$$\delta = A 10^{-2} p_{vac} \qquad (1)$$

where $A = 1.28$ is the experimental coefficient.

Oil B. The liberation of air proceeds rather violently, a column of white foam occupies almost the entire space over the oil surface. At this time we observed a rapid increase in the drop of the levels in the differential manometer. Then air liberation noticeably drops and after 30-40 min stops altogether. The manometer reading remains unchanged.

TABLE 2

Results of the Experiment on Determination of Coefficient of Liberation δ for Oil AMG-10F.

P_{vac} mm Hg	manometer reading Δ h cm	coefficient of liberation δ %	P_{vac} mm Hg	manometer reading Δh cm	coefficient of liberation δ %
115	14	1,4	500	63	6,3
200	27	2,7	560	70	7,0
215	35,5	3,55	595	77	7,7
315	37,5	3,75	610	85	8,5
375	47	4,7	660	27	8,7
400	51	5,1	720	91	9,1
420	59,5	5,95	745	95	9,5
495	66	6,6	747	96	9,6
500	64	6,4			

The results of the experiment are shown in Fig. 3 and in Table 3. As in the preceding case, all experimental points lie nicely on a straight line proceeding from the origin of the coordinates. The maximum coefficient of liberation (or coefficient of solubility) δ_{max} = = 8.7% when p_{vac} = 760 mm Hg can be represented also by formula (1) in which coefficient A = 1.11.

TABLE 3

Results of the Experiment on Determination of Coefficient of Liberation δ for Oil B

P_{vac} mm Hg	manometer reading Δh in cm	coefficient of liberation δ in %
100	12,5	1,25
200	23	2,3
300	33	3,3
400	53	5,3
500	57,5	5,75
600	67,5	6,75
660	76	7,6
747	84,5	8,45

Oil A. Liberation of air proceeds about the same as in the previous experiment. The coefficient of liberation increases rather rapidly; about 40 minutes afterwards it reaches its maximum value and in spite of vigorous shaking of the device it remains constant, which indicates termination of the liberation process.

The character of the change in the coefficient of liberation is similar to the other liquids.

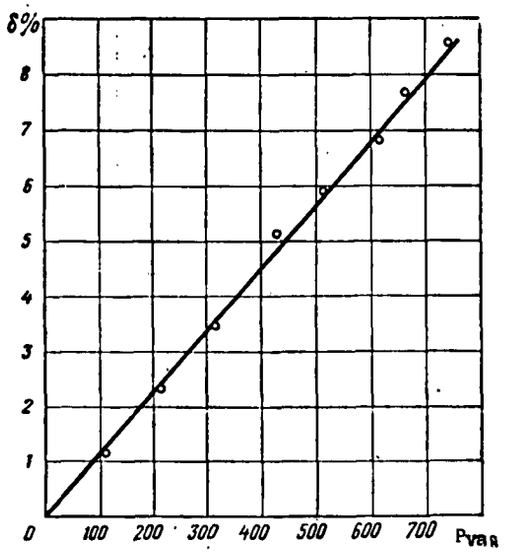

Fig. 3. Coefficient of liberation of oil B versus exhaustion p_{vac} (t = 20.5-21°).

The coefficient of liberation increases in proportion to the increase of evacuation. The equation of the experimental curve has a shape analogous to Formula (1), in which the coefficient A = 1.17.

The coefficient of solubility δ_{max} = 8.8%. The results of the investigations are shown in Tables 4 and 5.

TABLE 4

Values of Experimental Coefficient A for test liquids

Oil	Experimental value A	With consideration of error A_1
MG-10F	1,28	1,38
A	1,17	1,26
B	1,11	1,21

TABLE 5

Values of δ_{max} for investigated liquids

Oil	Experimental value δ_{max} in %	With consideration of error δ_{max} in %
MG-10F	9,72	10,62
A	8,8	9,53
B	8,7	9,42

Possible Errors of the Experiment

1. The obtained values of the coefficient of liberation should be considered underestimated since during the experiment the pressure of the liberated air in vessels 1 and 4 is at first added to the residual pressure.

The magnitude of the coefficient of liberation is reduced by a certain value Δ_1, which can be calculated by the following formula:

$$\Delta_1 = \frac{p_1 + p_2}{p_0} \delta, \qquad (2)$$

where p_1 is the residual pressure;

p_2 are the readings of the differential manometer;

p_0 is atmospheric pressure;

δ is the coefficient of liberation.

In our case the highest value is $\Delta_1 = 7.7\%$.

2. On displacement of the liquid in the manometer there is a change in the ratios of volumes V_1 and V_2, which leads to a decrease in the actual value of the coefficient of liberation. Calculation of the change of volumes leads to the correction

$$\Delta_2 = \frac{p_2}{p_0 V_1} \frac{S\Delta h}{2}, \qquad (3)$$

where V_1 is the volume of vessel 1;

S is the cross sectional area of the manometer 2;

Δh is the drop in the manometer readings.

On maximal evacuation $\Delta_2 = 0.6\%$. The total error of the instrument is $\Delta_1 + \Delta_2 = 8.3\%$.

CONCLUSIONS

1. In the present work we investigated the air content of three oils, AMG-10F, A, and B at atmospheric pressure and at room temperature.

We determine for these oils the experimental dependence of the coefficient of liberation on the degree of evacuation. This dependence bears a very specific character for all test liquids and is nicely described by the theoretical formula.

2. As a result of the experiment we determined the maximal coefficients of air liberation δ_{max} (at maximal evacuation) which enabled us to judge the capacity of the liquid for gas saturation at atmospheric pressure.

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